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Experimental Study on Paver Blocks Using Fly Ash–Treated Reclaimed Asphalt Pavement as Partial Replacement for Natural Coarse Aggregate: A Review

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Abstract:

The rapid growth of infrastructure development has increased the demand for construction materials, especially natural aggregates used in concrete production. At the same time, large quantities of waste materials such as Reclaimed Asphalt Pavement (RAP) are generated during road rehabilitation and maintenance activities. Disposal of RAP creates environmental concerns due to landfill requirements and resource wastage. The use of RAP as a replacement for natural coarse aggregate in paver block manufacturing offers a sustainable solution by reducing construction waste and conserving natural resources. Fly ash, an industrial by-product from thermal power plants, can further improve the properties of RAP-based concrete by enhancing workability, strength, and durability. This review paper presents a comprehensive study on the utilization of fly ash-treated RAP in concrete paver blocks. Various research findings related to RAP incorporation, fly ash stabilization, mechanical properties, durability performance, and sustainable construction applications are discussed. The paper highlights the significance of recycled materials in paver block production and identifies research gaps for future experimental investigations.
Keywords:..

Keywords — **Reclaimed Asphalt Pavement (RAP), Fly Ash, Paver Blocks, Sustainable Construction, Recycled Aggregate, Concrete Blocks, Durability, Waste Utilization**

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I. INTRODUCTION

Concrete paver blocks are widely used in pedestrian walkways, parking areas, low-volume roads, industrial flooring, and landscaping applications due to their strength, durability, and ease of maintenance. Conventional paver blocks are generally produced using natural aggregates, cement, sand, and water. However, the excessive extraction of natural aggregates contributes to depletion of natural resources and environmental degradation [11], [40].

In recent years, sustainable construction practices have encouraged the incorporation of waste and recycled materials in concrete production. Reclaimed Asphalt Pavement (RAP) is one of the most promising recycled materials obtained from the milling and rehabilitation of asphalt pavements. RAP consists of aggregates coated with aged bitumen, which influences its bonding behavior when incorporated into cement concrete [23], [24], [31].

The use of RAP in paver blocks can significantly reduce waste disposal problems while minimizing dependence on natural aggregates. Several studies have reported that RAP can serve as an alternative aggregate material in concrete and paving applications, promoting sustainable construction practices. However, RAP may reduce the mechanical performance of concrete due to weaker bonding between asphalt-coated particles and cement paste [4], [13], [15].

To overcome this limitation, fly ash can be incorporated as a supplementary cementitious material. Fly ash contributes to improved particle packing, pozzolanic activity, workability, and long-term durability. Researchers have shown that fly ash stabilization enhances the engineering properties of RAP-based materials by improving interfacial bonding and reducing permeability [22], [25], [26].

This review focuses on the potential use of fly ash-treated RAP as a partial replacement for natural coarse aggregate in concrete paver blocks. It summarizes previous studies related to RAP stabilization, fly ash incorporation, and paver block performance to establish a foundation for sustainable and eco-friendly paving material development [5], [16], [41].

II. NEED FOR THE STUDY

The construction industry produces a large amount of demolition and road rehabilitation waste, which creates environmental challenges. Reclaimed Asphalt Pavement (RAP) is commonly generated during road resurfacing operations. In many regions, RAP is either stockpiled or disposed of in landfills, leading to inefficient waste management.

Simultaneously, natural aggregate resources are rapidly depleting due to increasing infrastructure demands. Sustainable alternatives are therefore required to minimize environmental impacts and reduce construction costs.

The need for this study arises from the following aspects:

- Reduction in waste disposal problems associated with RAP.
- Conservation of natural aggregate resources.
- Effective utilization of industrial by-products such as fly ash.
- Improvement in sustainability of paver block production.
- Development of economical and environmentally friendly paving materials.

III. OBJECTIVE

The main objective of this study is to investigate the performance of paver blocks produced using fly ash-treated reclaimed asphalt pavement as a partial replacement for natural coarse aggregate.

Specific objectives include:

- To study the properties of cement, M-sand, coarse aggregate, RAP, fly ash, and water used in paver block production.
- To utilize RAP as a partial replacement for natural coarse aggregate.
- To evaluate the influence of fly ash addition on concrete paver blocks.
- To determine compressive strength at different curing periods.
- To evaluate water absorption, density, flexural strength, and efflorescence characteristics.
- To compare RAP-based paver blocks with conventional paver blocks.
- To promote sustainable construction using recycled and industrial waste materials.

IV. MATERIALS USED

The materials proposed for this study are selected based on their suitability for concrete paver block production and their contribution toward sustainable construction practices. Ordinary Portland Cement (OPC) 53 Grade is used as the primary binding material due to its high early strength, good durability characteristics, and wide application in precast concrete products. OPC 53 Grade is commonly preferred in paver block manufacturing because it provides adequate compressive strength and ensures proper bonding among aggregates [7], [31].

Manufactured Sand (M-sand) is used as the fine aggregate in this study owing to its uniform particle size distribution, improved workability, and consistent quality compared to natural river sand. The use of M-sand also supports sustainable construction by reducing dependency on natural sand resources. Previous studies have demonstrated that M-sand contributes to improved packing density and better performance in concrete paving blocks [19], [20].

Natural coarse aggregate with a particle size range of 6–12 mm is incorporated in the control mix for conventional paver block production. These aggregates provide structural stability, load-bearing capacity, and adequate strength to concrete. The selected aggregate size is suitable for paver block applications because it ensures good compaction and uniform distribution within the concrete matrix [13], [15].

Reclaimed Asphalt Pavement (RAP) is collected from local road rehabilitation and milling sites around Tiruchengode. RAP consists of aged asphalt-coated aggregates obtained from existing pavement layers. The utilization of RAP in concrete mixtures helps reduce waste disposal problems and minimizes the consumption of natural aggregates. Several studies have reported that RAP can be effectively used as a partial replacement material in paving applications when properly processed and proportioned [4], [5], [24].

Class F Fly Ash is incorporated as a supplementary material to enhance cementitious behavior and improve the performance of RAP-based concrete. Fly ash contributes to pozzolanic reactions, reduces permeability, and enhances the interfacial bonding between RAP particles and cement paste. In addition, fly ash improves long-term durability and promotes sustainable material utilization by recycling industrial waste products [22], [25], [26].

Potable tap water is used for both mixing and curing purposes to ensure proper hydration of cement and adequate strength development. Clean water free from impurities is essential to avoid adverse chemical reactions that may affect concrete quality. The use of potable water for concrete production is commonly recommended in experimental studies involving paver blocks and recycled aggregate concrete [6], [8].

V. Treatment of RAP

RAP particles possess asphalt coating that may reduce bonding between aggregate and cement paste. To improve bonding, RAP is treated using fly ash slurry coating.

The treatment process includes:

1. Collection and cleaning of RAP particles.
2. Preparation of fly ash slurry.
3. Surface coating of RAP using fly ash slurry.
4. Air drying before mixing.
5. Use of treated RAP in paver block production.

The fly ash coating helps improve surface roughness, bonding ability, and overall performance of RAP-based concrete.

VI. Literature Review

The use of reclaimed asphalt pavement (RAP) and fly ash in concrete and pavement applications has gained significant attention due to increasing concerns related to environmental sustainability, resource conservation, and waste management. Researchers have extensively studied RAP as a replacement for natural aggregates and fly ash as a supplementary cementitious material. The following literature provides a detailed understanding of RAP-treated paver blocks and sustainable paving materials.

A. Reclaimed Asphalt Pavement in Concrete Applications

Giulia Masi, Alessandra Michelacci, Stefania Manzi, and Maria Chiara Bignozzi (2022) investigated RAP collected from five different rehabilitation sites in Italy. The researchers observed that RAP particles contain aged asphalt coatings that influence concrete bonding behavior. Their findings indicated that RAP can successfully replace natural aggregates in concrete, although higher RAP content tends to reduce compressive strength due to weaker interfacial transition zones between RAP particles and cement paste [1].

Ahmed H. Alwathaf, Mu'tasim Abdel Jaber, and Yasser M. Hunaiti (2025) studied RAP concrete mixtures and reported that increasing RAP content decreases compressive and splitting tensile strength. However, flexural performance improved at lower RAP replacement levels because of improved stress distribution through bitumen-coated particles. The study also concluded that the addition of silica fume and superplasticizer could partially recover lost strength [3].

KE Hassan, JJ Brooks, and M Erdman (2000) examined ordinary Portland cement concrete containing RAP aggregates using a maximum packing approach. Their study demonstrated that RAP can replace a portion of natural aggregate without causing severe performance reduction when mix design optimization is applied [31].

MK Diptikanta Rout et al. (2023) investigated RAP aggregate in rigid pavement concrete. The researchers observed that washed RAP performed better than untreated RAP due to improved aggregate surface quality. The optimum mix was found at 40% RAP replacement combined with zirconia silica fume, which improved mechanical strength and pavement suitability [15].

B. Fly Ash Stabilization of RAP

Sireesh Saride, A. Deepti, T. Someshwar Rao, J. Sarath Chandra Prasad, and R. Dayakar Babu (2014) evaluated fly ash-stabilized RAP for pavement base design. The researchers concluded that fly ash significantly improved resilient modulus, stiffness, and load-bearing capacity. The optimum fly ash content was identified as approximately 30%, beyond which strength gain was limited [26].

Menglim Hoy, Suksun Horpibulsuk, Runglawan Rachan, Avirut Chinkulkijniwat, and Arul Arulrajah (2016) investigated RAP stabilized with fly ash. The results indicated that cementitious gels such as calcium alumino-silicate hydrate (C-A-S-H) formed within RAP mixtures, increasing compressive strength and durability [25].

Maheshbabu Jallu, Arul Arulrajah, Sireesh Saride, and Robert Evans (2020) studied fly ash stabilization of RAP in pavement layers. Their results confirmed that fly ash significantly improved resilient modulus and stiffness properties. The study also reported enhanced durability and reduced moisture sensitivity [27].

Deepti Avirneni and Sireesh Saride (2016) analyzed the durability of fly ash-treated RAP under repeated wetting and drying cycles. The results showed low strength loss and minimal material deterioration after repeated environmental exposure, proving the long-term stability of fly ash stabilization [29].

Menglim Hoy et al. (2017) studied geopolymer stabilization of RAP using fly ash and slag binders. The research demonstrated improved compressive strength, modulus of elasticity, and long-term performance, making RAP suitable for sustainable pavement construction [28].

C. RAP in Paver Block Production

Sumit Nandi and GDRN Ransinchung (2021) investigated pervious paver blocks containing RAP aggregates. Their research found that up to 50% RAP replacement can be used without significant performance loss. Density and compressive strength decreased slightly, but abrasion resistance and sustainability benefits increased [13].

Nabil Hossiney, Hima Kiran Sepuri, Mothi Krishna Mohan, Arjun HR, Santhosh Govindaraju, and Jorisa Chyne (2020) evaluated alkali-activated paver blocks made with RAP aggregates. The study concluded that increasing RAP reduced compressive strength and abrasion resistance; however, the paver blocks still satisfied pedestrian-use requirements [6].

Yeswanth Paluri, S.R.R. Teja Prathipati, Vijay Kunamineni, and V. Bhavitha Chowdary (2025) developed geopolymer paver blocks incorporating RAP and fly ash. Results indicated that although RAP slightly reduced workability and strength, the final blocks met the required standards of IS 15658 and provided improved durability and sustainability [2].

Veligatla Ditendra et al. (2025) investigated paver blocks produced using RAP, fly ash, and GGBS. Their research found that supplementary cementitious materials compensated for strength reduction caused by RAP and enhanced durability properties [4].

Nikhil Saboo et al. (2020) investigated fly ash-based paver blocks prepared for low-volume roads. The study concluded that fly ash replacement up to 40% can be effectively used without major performance loss [7].

6.4 Sustainable Construction and Waste Utilization

Tommy Iduwin et al. (2024) reviewed the application of solid waste materials in pavement construction. Their findings showed that waste materials such as fly ash, RAP, plastic waste, and scrap tires can improve pavement performance while reducing environmental pollution [11].

Pradeep Kumar Gautam et al. (2018) reviewed recycled materials in flexible pavement systems and highlighted that sustainable construction significantly reduces natural resource depletion and construction costs [40].

Manuel Contreras-Llanes et al. (2023) studied recycled construction and demolition waste in pavement blocks. Results demonstrated that up to 50% replacement of natural aggregates could be used while maintaining strength, abrasion resistance, and water absorption performance [20].

Farah Kdous et al. (2026) reviewed durability properties of RAP concrete and concluded that RAP performance strongly depends on treatment methods, mix proportions, and supplementary cementitious materials. Fly ash and slag were identified as beneficial additives that improve bonding and durability [41].

D. Summary of Literature

The reviewed studies indicate that Reclaimed Asphalt Pavement (RAP) is a promising sustainable material for concrete and paver block production due to its potential to reduce natural aggregate consumption and construction waste. However, untreated RAP generally leads to a reduction in compressive strength because of weak bonding between asphalt-coated particles and cement paste. Several researchers reported that the incorporation of fly ash enhances particle interaction, improves pozzolanic activity, and contributes to better durability and long-term performance of RAP-based mixtures.

Most studies recommend RAP replacement levels ranging from 30% to 50% to achieve acceptable mechanical and durability properties. Similarly, fly ash contents between 20% and 30% have been identified as effective in improving strength development, reducing permeability, and enhancing microstructural bonding in RAP-treated mixtures. Although numerous studies have investigated RAP and fly ash individually or in pavement base applications, limited research has been conducted on fly ash surface-treated RAP in conventional concrete paver blocks. Therefore, further investigation is required to evaluate the combined effect of RAP and fly ash treatment on the performance of concrete paver blocks.

VII. Research Gap

Although numerous studies have investigated the use of Reclaimed Asphalt Pavement (RAP) and fly ash in pavement construction and concrete applications, several research gaps still exist in the field of paver block manufacturing. Previous research has mainly focused on RAP utilization in pavement base layers, geopolymer concrete, and asphalt recycling. However, limited studies have explored the combined use of fly ash-treated RAP as a partial replacement for natural coarse aggregate in conventional concrete paver blocks.

The existing literature reveals several important research gaps in the use of reclaimed asphalt pavement (RAP) for paver block production. Most previous studies have focused on the direct replacement of natural aggregates with RAP without considering surface treatment methods to improve bonding performance. Limited research has been carried out on the use of fly ash slurry coating for RAP particles to enhance the interfacial bonding between RAP and cement paste. In addition, very few studies have examined the combined influence of RAP and fly ash in conventional concrete paver blocks. Most available research primarily investigates RAP in pavement base layers or geopolymer systems rather than in Ordinary Portland Cement (OPC)-based paver blocks. There is also insufficient information regarding the optimum replacement percentage of RAP for achieving balanced mechanical and durability performance. Furthermore, limited data are available on important properties such as density, efflorescence, water absorption, and long-term durability of RAP-treated paver blocks. The long-term field performance of fly ash-treated RAP concrete under practical paving conditions also remains largely unexplored, highlighting the need for further experimental investigation.

From the literature survey, it is evident that more experimental investigations are required to establish the feasibility of fly ash-treated RAP in paver block production. Therefore, this study attempts to fill this gap by evaluating the performance of paver blocks prepared using treated RAP and fly ash.

VIII. Experimental Methodology

The proposed experimental methodology is designed to investigate the feasibility of using fly ash-treated Reclaimed Asphalt Pavement (RAP) as a partial replacement for natural coarse aggregate in the production of concrete paver blocks. The methodology includes material collection, characterization, RAP treatment, mix preparation, casting, curing, testing, and comparative performance evaluation. This approach aims to examine the suitability of RAP and fly ash for sustainable paver block manufacturing while reducing the consumption of virgin aggregates and promoting environmentally friendly construction practices [11], [23], [40].

The materials required for the study are collected from reliable and locally available sources. Ordinary Portland Cement (OPC) 53 Grade is used as the primary binding material due to its good strength development characteristics. M-sand is used as fine aggregate, while natural coarse aggregate of size 6–12 mm serves as the conventional aggregate component. Reclaimed Asphalt Pavement (RAP) is collected from road rehabilitation sites around Tiruchengode to ensure local applicability and waste utilization. Class F fly ash is selected as a supplementary treatment material because of its pozzolanic properties and ability to improve interfacial bonding. Potable tap water is used for mixing and curing. Similar materials have been utilized in RAP-based paver block and pavement studies to improve sustainability and reduce environmental impact [4], [5], [7].

Prior to mix preparation, material characterization is carried out to determine the engineering properties of each constituent material. Tests such as specific gravity, sieve analysis, water absorption, bulk density, and particle grading are performed to ensure compliance with standard concrete production requirements. These properties play a crucial role in understanding particle distribution, density variation, and water demand of RAP-containing mixtures. Previous studies have emphasized the importance of proper material characterization to evaluate the suitability of recycled aggregates in concrete applications [12], [15], [31].

To improve the bonding behavior between RAP particles and cement paste, RAP is treated using a fly ash slurry coating process. Initially, RAP particles are cleaned to remove adhered dust and loose contaminants. A slurry is prepared by mixing fly ash with water to obtain a uniform coating medium. The RAP particles are then coated evenly with the slurry and allowed to air dry for a specified period before being incorporated into the concrete mix. This treatment enhances surface roughness and improves the interfacial transition zone between RAP and cement paste, which is often considered the weak zone in RAP concrete. Fly ash stabilization has been reported to improve strength, stiffness, and durability performance of RAP-based materials [22], [25], [26].

The mix design consists of a control mix prepared using conventional materials and experimental mixes incorporating RAP as a 50% replacement for natural coarse aggregate. Different fly ash percentages of 0%, 10%, 20%, and 30% are used to identify the optimum treatment level. The selected proportions are intended to evaluate the combined influence of RAP replacement and fly ash treatment on paver block performance. Similar replacement percentages have been successfully investigated in previous studies involving recycled aggregates and RAP-based paver blocks [13], [14], [19].

Concrete paver blocks are cast by batching the required quantities of cement, M-sand, coarse aggregate, RAP, and fly ash according to the selected mix proportions. Dry mixing is first carried out to ensure uniform distribution of materials, followed by gradual addition of water to obtain workable concrete. The prepared mix is placed into paver block moulds and compacted properly to minimize voids and achieve adequate density. The specimens are demoulded after 24 hours and prepared for curing. Similar casting methods have been adopted in sustainable concrete paver block investigations [6], [20], [21].

After demoulding, the paver blocks are cured using water curing for periods of 7, 14, and 28 days. Proper curing is essential for hydration of cement and development of mechanical strength. The curing duration allows evaluation of early-age and long-term performance of RAP-based paver blocks. Studies have shown that curing conditions significantly influence the strength and durability of recycled aggregate concrete products [8], [29], [33].

The performance of the prepared paver blocks is evaluated through a detailed testing program. Mechanical properties are assessed using compressive strength, flexural strength, and abrasion resistance tests. Physical properties such as density and water absorption are measured to evaluate compactness and porosity characteristics. Durability performance is examined through efflorescence testing, surface quality assessment, and Scanning Electron Microscopy (SEM) analysis to study the microstructural interaction between RAP particles and cement paste. Similar testing approaches have been widely adopted in RAP and fly ash-based paver block research [9], [10], [41].

Finally, the obtained results are compared with conventional paver block specimens to evaluate improvements in strength, durability, water absorption, and overall performance. The comparative analysis helps determine the optimum fly ash-treated RAP mix suitable for practical paving applications. The study aims to identify a sustainable alternative material that can effectively reduce waste disposal problems, conserve natural aggregates, and provide satisfactory engineering performance for paving construction [16], [17], [42].

IX. Expected Outcomes

The expected outcomes of this study are centered on developing sustainable and high-performance concrete paver blocks through the utilization of fly ash-treated Reclaimed Asphalt Pavement (RAP) as a partial replacement for natural coarse aggregate. One of the major anticipated outcomes is the reduction in the consumption of natural aggregates, which are increasingly depleted due to rapid infrastructure development. By replacing a portion of conventional coarse aggregate with RAP, the study aims to conserve natural resources and promote responsible material usage in construction practices [11], [23], [40].

Another important expected outcome is the effective utilization of RAP waste generated from road rehabilitation and pavement milling operations. Large quantities of RAP are often disposed of in landfills, creating environmental and storage challenges. Incorporating RAP into paver block production provides a beneficial reuse pathway for this waste material, thereby reducing disposal problems and supporting circular economy principles in the construction industry [24], [30], [42].

The study is also expected to improve sustainability in paver block manufacturing through the combined use of RAP and fly ash. Fly ash, being an industrial by-product, contributes to reducing cement consumption and improving the environmental profile of concrete products. The integration of recycled materials is anticipated to lower carbon emissions, reduce energy consumption associated with aggregate extraction, and minimize the environmental footprint of paving block production [4], [16], [17].

An additional expected outcome is the identification of the optimum fly ash treatment percentage that provides the best balance between mechanical strength, durability, and water absorption characteristics. Different fly ash contents are expected to influence the bonding behavior between RAP particles and cement paste. The study aims to determine the most effective fly ash dosage that enhances interfacial bonding and improves the performance of RAP-based paver blocks [22], [25], [26].

The prepared paver blocks are also expected to exhibit acceptable compressive strength, flexural strength, abrasion resistance, and durability properties suitable for practical paving applications. The use of treated RAP may improve surface texture and internal bonding, resulting in enhanced structural integrity and reduced permeability. Properly treated RAP aggregates may compensate for the weaker bonding usually associated with recycled asphalt materials [14], [15], [41].

Furthermore, the research is expected to contribute to the development of cost-effective and eco-friendly paving blocks. Since RAP is a recycled material obtained from existing pavements, its use can potentially reduce raw material costs and decrease dependence on virgin aggregates. The incorporation of fly ash may also reduce binder costs while improving long-term durability. Overall, the study aims to demonstrate that fly ash-treated RAP paver blocks can provide an economical, sustainable, and technically feasible alternative to conventional concrete paving units [5], [13], [19].

X. CONCLUSION

The present review highlights the growing importance of sustainable construction materials in the development of concrete paver blocks. The use of Reclaimed Asphalt Pavement (RAP) as a partial replacement for natural coarse aggregate offers a promising solution for reducing construction waste and minimizing the excessive consumption of virgin aggregates. Several previous studies have demonstrated that RAP can be effectively incorporated into concrete and paving applications, although untreated RAP may lead to reductions in strength due to weaker bonding between asphalt-coated particles and cement paste [13], [15], [31].

The incorporation of fly ash as a treatment material further enhances the potential of RAP-based paver blocks by improving particle bonding, interfacial transition zones, and durability performance. Fly ash treatment

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